Electronically Reconfigurable Patches for Transmit-array Structures at 12GHz

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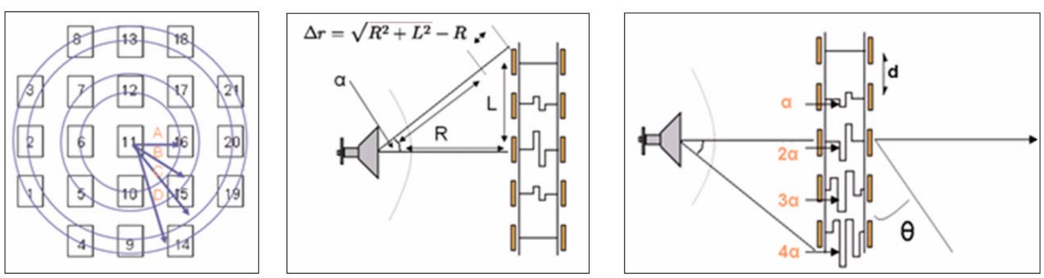
Introduction

The aim of the paper below is to develop certain active radiating elements for reconfigurable patch arrays. In literature it could be found different possibilities to obtain feasible reconfigurable antennas, whether placing the active circuitry in the transmission lines or directly over the patch. In this paper, the second option is chosen and active radiating elements are analyzed, designed, simulated and prototyped. Finally, measurements of these prototypes are shown. This work is part of a more complete and ambitious project to design and prototype reconfigurable transmit-array structures for microwave applications.

Transmit-array Concept

The basics of this sort of structures are easy to be understood: an electromagnetic wave with specific front wave properties is received, processed in a particular way (change in the radiation pattern, amplification...) and finally the wave is retransmitted. The main idea with this device consists of placing it in front of a particular antenna, in order to obtain two main advantages: correction of the phase error of an antenna and configuration of a new radiation pattern. Figure 1 shows its working principle.



a) b) c)

Fig.1. a) Transmit-array view b) Phase error correction, c) Radiation pattern modification.

Active Element Design

Although the most important efforts in literature have been focused in locating active circuitry in transmission lines, the particular distribution of elements in the antennas in which reconfigurability is going to be added, and the lack of space in the transmission line part make it advisable to place the active circuitry directly over the patch. Figure 2 shows the two options.

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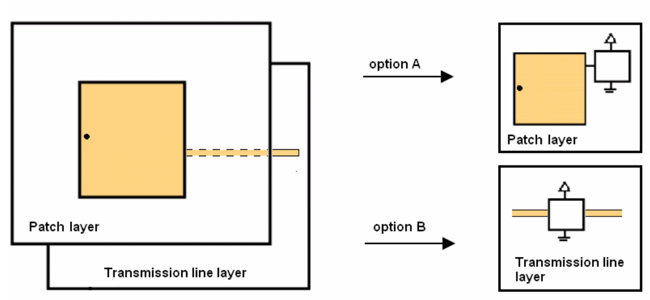


Fig.2. option A: active circuitry over patch; option B: active circuitry in transmission lines.

Every radiating element presents a variable circuital behaviour in frequency, due to the equivalent impedance of the patch at each frequency. Modifying the patch equivalent impedance it is possible to change the working frequency of the patch and, as a consequence, the phase behaviour of its S_{11}. Figure 3 presents the desired behaviour of the phase variation.

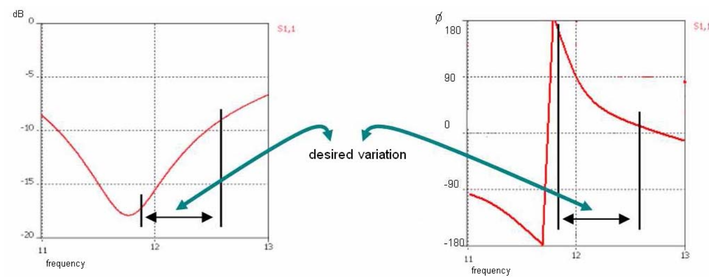


Fig.3. Desired patch phase behaviour.

It is necessary to define a proper circuital model for the active patch in order to design and simulate an adequate structure. Figure 4 shows the selected model (that has been verified with electromagnetic simulation software). Notice that the model for the active circuit should be accurate enough, even though the position of the active circuit over the patch is not taken into account. This model will be used as an initial step to define parameters (L's, C's…) for simulations with powerful electromagnetic simulators (in this case, Microwave Studio CST 2006).

This selected model includes not only the circuital equivalent model but also some fabrication constraints (via holes to ground plane, etc.)

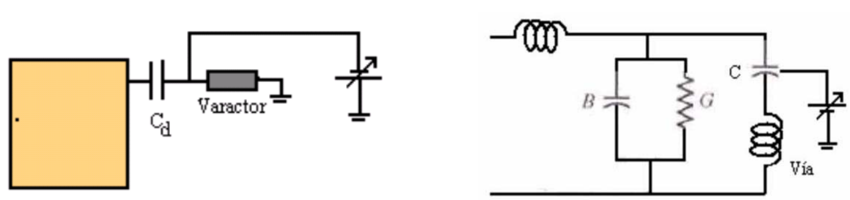
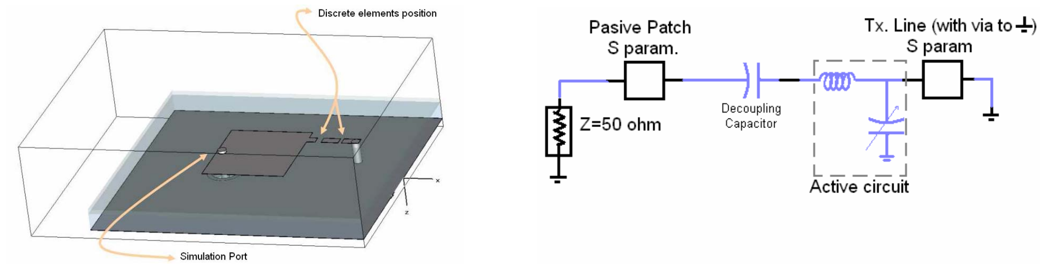


Fig.4. Active patch circuital model.

The essential element in the defined model is a varactor that will introduce the proper circuit variation.

Active Element Simulations

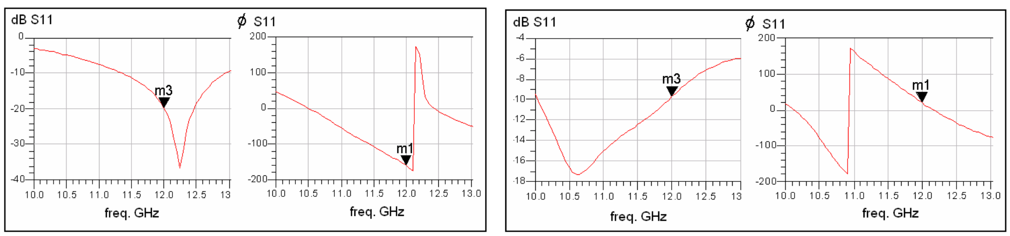
For the sake of completeness, two simulation models are established: the first one (figure 5.a) implies simulations with CST, including all the elements (circuitry included). The second one (figure 5.b) implies simulations for the different parts of the antenna and final result with the connexion of a variety of S parameters boxes.



a) b)

Fig.5. Active patch circuital model for simulation, a) simulation model with CST, b) simulation model with cascade of S param. boxes.

Although the two models are valid, the first one is more rigid and the circuitry that could be added is simpler than the one needed. For this reason, the second model is referred. Figure 6 shows simulations results for the edge values of the varactor selected.



a) b)

Fig.6. simulation results for the second model, a) simulation with Cmin, b) simulation with Cmax.

Active Element Prototypes and Measurements

Once the simulation stage is concluded and the structure parameters are selected, prototypes are defined and built. Figure 7 presents mask and built prototype (notice the detail of the active circuit and its dimensions).

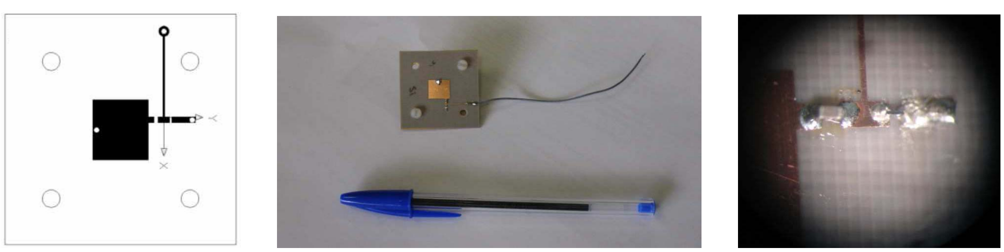
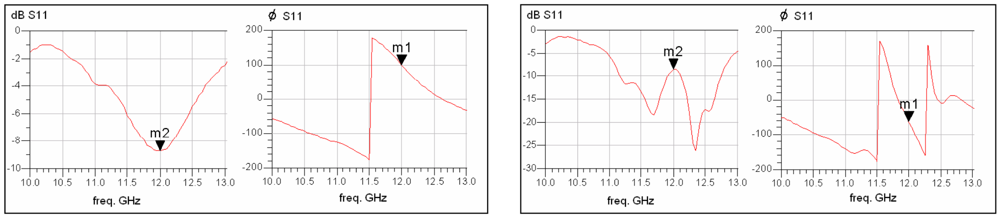


Fig.7. a) Prototype mask, b) Patch prototype, b) Active circuit detail.

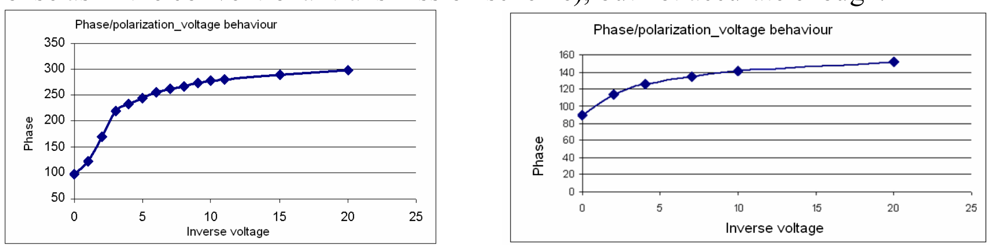
Two measurement methods are defined, the first one obtaining the phase behaviour measuring the reflection of the patch (is the easiest method, but an assumption has been considered: same phase behaviour in transmission and in reflection); the second one implies a conventional transmission measurement scheme. Figure 8 shows the prototype measurement results for the first method, for the edge values of the varactor used (Vmin (Cmin), Vmax (Cmax)).



a) b)

Fig.8. prototype results, a) result with Cmin (V=0v), b) result with Cmax (V=20v).

Comparing the results of the two methods (figure 9.a and 9.b), it could be noticed that the assumption considered is partially valid (the phase variation is obtained, but not the same response as in the conventional transmission scheme), but not accurate enough.



a) b)

Fig.9. prototype results for C variations, a) results with a reflection measurement model, b) results with a transmission measurement model.

Conclusions

In this research work, it has been tried to design, simulate and manufacture electronically reconfigurable active patches at 12 GHz. The most important advantage of this kind of active elements remains in the possibility of modifying the phase behaviour of each radiating element of an array in order to modify the antenna steering vector and its radiation pattern. In this paper some design criteria, simulation results and prototype measurements have been presented.

Acknowledgement

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